Research Article

Quantitative and Qualitative Traits of Sunflower Genotypes as Influenced by Nitrogen Application through Fertigation

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Abstract | Fertigation is the application of dissolved fertilizer especially nitrogen through irrigation for correcting nutrient deficiencies of plants. A field study was conducted in Tandojam for two consecutive years in autumn 2018 and 2019. The experiment was replicated thrice in randomized complete block design. Different doses of nitrogen as broadcasting and fertigation (0, 75, 100, 125 kg N ha^{-1} in two and three equal splits given at sowing time, 1st, 2nd and 3rd irrigations, respectively) were applied to two sunflower genotypes (HO-1 and Hysun-39). Data analysis revealed nitrogen fertigation, genotypes and their interaction substantially ($P \leq 0.05$) affected growth and yield traits of sunflower. Greater seed yield (kg ha^{-1}) and the oil content (%) were documented in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation), followed by N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation). In between genotypes, higher seed yield (kg ha^{-1}) and oil content (%) were recorded in HO-1 as compared to Hysun-39. As regards interactions, enhanced seed yield (kg ha^{-1}) and oil content (%) were registered in the interaction of N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcast at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) × HO-1. It was concluded from the results that nitrogen dose should be divided into three splits and applied at sowing time through broadcasting and fertigated at 1st and 2nd irrigation, respectively. Variety HO-1 should be preferred to obtain enhanced sunflower seed yield under Tandojam climatic conditions.

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Introduction

Pakistan is facing acute shortage of edible oil. The demand for edible oil in Pakistan is increasing with the uncontrollable increase in population. Its indigenous production is below the consumption levels with a very wide gap between production and consumption. This gap is bridged through import of edible oil worth more than Rs. 45.0 billion annually. Pakistan ranks 3rd largest edible oil importing country in the world (GoP, 2020). The country's oil requirement was about 2.966 million tons in which 0.83 million tons (28%) were locally produced and the rest edible oil was imported. The edible oil requirements have increased from 0.3 million tons to 1.95 million tons. But the domestic production of edible oil has remained inadequate and fluctuating for the last couple of decades. These fluctuations are due to indigenous marketing, low support price and high cost of production which is making these crops non-profitable to

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the farmers. Only sunflower has shown some positive results in area and production compared to other oil crops (Khan and Inamullah, 2019). Oilseeds have an enormous significance as an essential part of human diet after cereal and sugar crops in Pakistan (GoP, 2019). Vegetable oil is considered as more suitable for health as compared to "ghee" from animal source because it contains less cholesterol and unsaturated fats (Masood, 2014). Sunflower is considered as the 4th highest source of vegetable oil at world level after soybean, rapeseed and palm and 2nd largest source of edible oil after cottonseed in Pakistan (Keerio *et al*., 2020). This crop fulfils about 14% cooking oils needs of Pakistan. Sunflower has the potential to bridge the gap between consumption and domestic oil production in Pakistan (Nasim *et al*., 2012). It is well fitted to climatic conditions and current cropping system of Pakistan (Mahmood *et al*., 2018). In Pakistan sunflower is being cultivated in autumn and spring (PARC, 2019). Buriro *et al*. (2015) has disclosed that seed of sunflower contains nearly 47% oil, linoleic acid and vitamins A, D, E and K. The consumption of sunflower oil reduces the blood cholesterol level (Debaeke *et al*., 2021). Genotype selection and fertilizer application are important agro-management practices that increase crop growth and production (Sheoran *et al*., 2014). The hybrids are further constant and extremely self-fertile having uniformity at maturity and high yield performance (Wajid *et al*., 2017). Nitrogen is a plant nutrient that has direct influence on quantitative and qualitative traits of crop (Alves *et al*., 2017). It is the critical limiting nutrient for the plants, absorbed in plenty as nitrate, urea and ammonium. Nitrogen is a primary plant nutrient which plays an important role in plant growth and development, and ultimately causes increase or decrease in yield and quality of the crop produce (Nasim *et al*., 2012). The rate and source of nitrogen have a significant impact on the sunflower yield and other agronomic traits (Yassen *et al*., 2011). Nitrogen fertigation is the technique of applying dissolved fertilizer to crops during their growth stages through an irrigation system. It is used to spoon feeding additional nutrients or correct nutrient deficiencies detected in plant tissue analysis (Daniela *et al*., 2018). Nitrogen fertigation provides an excellent opportunity to maximize yield and minimize environmental pollution by increasing fertilizer use efficiency. Fertigation reduces fertilizer dose and increases return on the fertilizer (Shabbir *et al*., 2015). This investigation gives an insight into optimizing sunflower fertilization as well as role of nitrogen towards yield and yield contributing traits of sunflower. The study was aimed at evaluating the comparative impact of nitrogen application through fertigation and conventional method broadcasting on seed and oil yield of sunflower under Tandojam conditions.

Materials and Methods

The field study was conducted in Tandojam conditions during autumn 2018 and repeated in 2019. The experiment was laid out in three replicated randomized completed block design with factorial arrangements. The net plot size of experimental unit was 30 m^2 (6 m x 5 m). The treatments comprised of different doses of nitrogen as broadcast and fertigation (0, 75, 100, 125 kg N ha^{-1} in two and three equal splits given at sowing time, 1st, 2nd and 3rd irrigations, respectively) and two sunflower genotypes *i.e*. HO-1and Hysun-39. The land was prepared thoroughly by applying two dry ploughings, followed by heavy soaking doses. After that when soil came in workable conditions, the laser land leveler was used to maintain the level of land, followed by two cross-wise ploughings with cultivator. The bunds and feedings channel were prepared to separate each replication and treatment. The seed was sown by hand drill in separate plots during 2nd week of August, each year. Nitrogen was applied as per treatments in the form of Urea (46% N). Phosphorus and potassium were applied at their recommended doses of 50 and 50 kg ha^{-1} in-the forms of SSP (18% P_2O_5) and SOP (50% K_2O). Weeding was done before 1st and 2nd irrigation.

Data collection

The data was recorded on following parameters:

Plant height (cm): The plant height was measured in centimeters from base to tip with measuring tape in all tagged plants from each experimental unit and their average was calculated.

Head diameter (cm): The head diameter was measured with measuring tape in all selected plants in centimeters and the mean was computed.

Seed weight head^{-1} (g): The weight of seeds head^{-1} was measured by using digital weight balance and the average was calculated.

Biological yield (kg ha^{-1}): The biomass of total harvested and dried plants was measured in kilograms

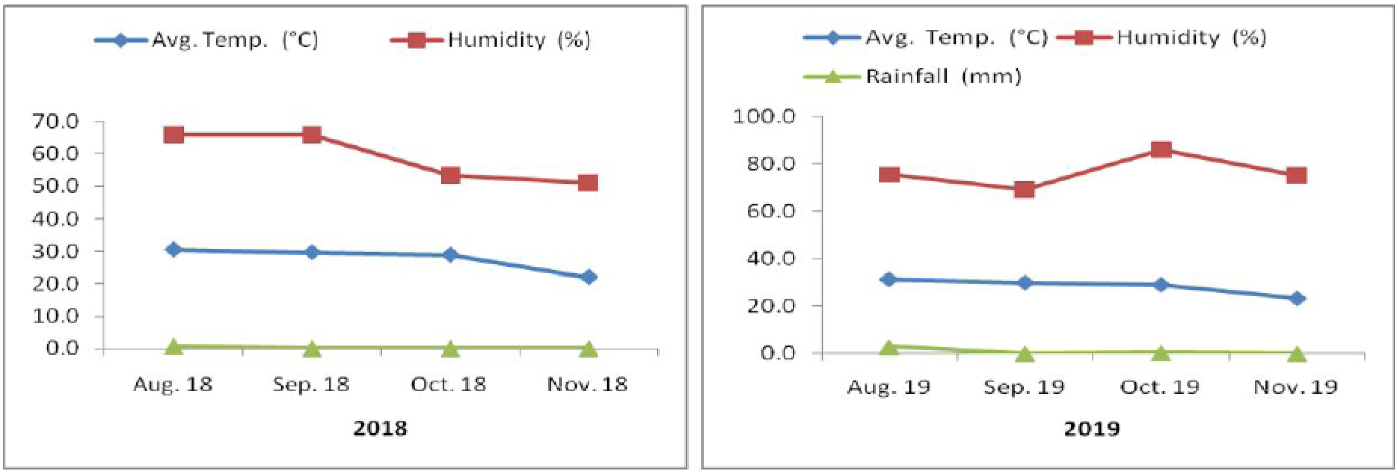

Figure 1: *Tandojam weather data of 2018 and 2019 during sunflower growth period.*

Table 1: *Physico-chemical analysis of experimental soil (2018 and 2019).*

Soil Parameter	Values
Soil texture	
Clay (%)	38.00
Silt (%)	41.50
Sand (%)	20.50
Textural class	Silt clayey loam
Chemical properties	
Soil pH	7.98
EC (dS m^{-1})	2.370
Organic matter (%)	0.500
P available (mg kg^{-1})	9.000
K extractable (mg kg^{-1})	0.890
Total N (%)	0.021

by using digital weight balance before threshing seeds from heads and then average was calculated.

Seed yield (kg ha^{-1}): The seed obtained from heads of total harvested plants after drying was weighed in kilograms by using digital weight balance average was worked out.

Oils content (%): The oil content was determined by taking 10 grams of seed through Soxhlete apparatus (for each treatment) available at Institute of Oilseeds Research, ARC, Tandojam. The oil content % was measured by using the formula: Oil weight (g) ÷ Seed sample weight (g) x 100.

Chlorophyll content (mg g^{-1}): The chlorophyll content was recorded in mg g^{-1} with digital chlorophyll meter from the leaves of living plants in the field during peak vegetative growth of the plants.

Crop growth rate (g m^{-2} day^{-1}): The growth rate of crop was noted from the plants selected at random through the formula: (Weight 2 – Weight 1) ÷ (Time 2 –Time 1) at the climax of growth period of crop.

Statistical analysis

The recorded data was analyzed statistically through the application of analysis of variance technique by involving software Statistix version 8.1 (Statistix, 2006). The LSD test was applied 0.05 for evaluating the difference of various treatments.

Physico-chemical analysis of soil

The Soil Auger was used for taking soil samples before sowing and after harvesting of crop from different five locations of the experimental area at the depth of 0-30 cm. The samples were dried under sun, then grinding and sieving in 2 mm was done and later on kept in containers of plastic. After that different properties of physical as well as chemical nature of the soil were done. The procedure adopted was that of Rayan *et al.* (2001) (Table 1).

Weather data

Tandojam weather data during growing season of crop was collected from the Meteorological Station established at Tandojam. The weather data on monthly basis is given as under in the Figure 1.

Results and Discussion

Plant height (cm)

Nitrogen application through fertigation caused marked ($P<0.05$) effects on plant height (cm) of sunflower genotypes (Table 2). Tallest plants were observed under N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓

Table 2: *Plant height (cm) and head diameter (cm) of sunflower as affected by nitrogen fertigation and genotypes.*

Fertigation method		Plant height (cm)			Head diameter (cm)		
		Genotypes		Mean	Genotypes		Mean
		HO-1	Hysun-39		HO-1	Hysun-39	
N_1	Control (No nitrogen)	177.7	174.7	176.2 E	27.5	26.8	27.3 D
N_2	75 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	188.0	180.3	184.2 DE	29.3	27.0	28.1 D
N_3	75 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd; both as fertigation)	193.0	190.0	191.5 CDE	32.8	30.3	31.6 CD
N_4	75 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	194.7	192.0	193.3 DE	33.5	30.8	32.2 BCD
N_5	100 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	199.7	196.7	198.2 BCD	35.7	32.5	34.1 BC
N_6	100 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	204.0	203.7	203.8 A-D	36.0	33.7	34.8 BC
N_7	100 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	206.0	207.0	206.5 A-D	37.2	34.7	35.9 ABC
N_8	125 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	228.3	217.3	222.8 AB	38.2	35.7	36.9 AB
N_9	125 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	220.3	212.7	216.5 ABC	37.7	34.8	36.3 ABC
N_{10}	125 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	231.7	227.0	229.3 A	41.7	38.0	39.8 A
Mean		204.3	200.1	--	35.0 A	32.4 B	--
Variable		Fert (F)	Geno (G)	F x G	Fert (F)	Geno (G)	F x G
CV		11.53			12.61		
SE		13.459	6.0191	19.034	2.453	1.097	3.469
P value		0.005	0.489	1.000	0.000	0.027	1.000
$LSD_{0.05}$		27.246	-	-	4.967	2.221	-

at 3rd irrigation), followed by N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation). However, smallest plants were noted under N_1 = control (no nitrogen). Among genotypes, taller plants were noticed in HO-1 whereas smaller ones were registered in Hysun-39. In case of interactive effects, greatest height of plants was obtained in the interaction of N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) with genotype HO-1 while lowest plant height was registered in the interaction of N_1 = control (no nitrogen) with genotype Hysun-39.

Head diameter (cm)

The analysis of data indicated that application of nitrogen through fertigation substantially ($P<0.05$) influenced on head diameter (cm) of sunflower (Table 2). The largest head diameter was recorded under N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation). Whereas, N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation) ranked 2nd in head diameter. Nevertheless, lowest head diameter was documented under N_1 = control (no nitrogen). Genotype HO-1 gave greater head diameter over Hysun-39. The interaction of N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) with genotype HO-1 produced greatest head diameter and that of N_1 = control (no nitrogen) with Hysun-39 gave least head diameter (cm).

Seed weight head^{-1} (g)

The data analysis revealed that seed weight head^{-1} (g) of sunflower was affected markedly ($P\leq0.05$) by application of nitrogen through fertigation (Table 3). In case of nitrogen application methods, N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) gave higher seed weight head^{-1} (g). N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd

Table 3: *Seed weight head^{-1} (g) and biological yield (kg ha^{-1}) of ssunflower as affected by nitrogen fertigation and genotypes.*

Fertigation method		Seed weight head^{-1} (g)			Biological yield (kg ha^{-1})		
		Genotypes		Mean	Genotypes		Mean
		HO-1	Hysun-39		HO-1	Hysun-39	
N_1	Control (No nitrogen)	177.7	378.0	440.5 C	3624	3520	3572 C
N_2	75 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	188.0	387.3	452.5 BC	3986	3656	3821 BC
N_3	75 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd; both as fertigation)	193.0	415.3	466.8 BC	4078	4040	4059 AB
N_4	75 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	194.7	425.0	485.3 BC	4114	4045	4080 AB
N_5	100 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	199.7	441.7	494.8 BC	4119	4117	4118 AB
N_6	100 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	204.0	442.3	497.0 BC	4173	4158	4165 AB
N_7	100 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	206.0	482.7	520.5 ABC	4211	4163	4187 AB
N_8	125 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	220.3	493.3	532.7 AB	4353	4250	4302 A
N_9	125 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	228.3	488.0	523.3 AB	4253	4246	4249 AB
N_{10}	125 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	231.7	530.3	584.5 A	4379	4287	4333 A
Mean		551.2 A	448.4 B	--	4129	4048	--
Variable		Fert (F)	Geno (G)	F x G	Fert (F)	Geno (G)	F x G
CV		13.87			9.24		
SE		40.021	17.898	56.599	218.21	97.586	308.59
P value		0.038	0.000	0.998	0.037	0.414	0.999
$LSD_{0.05}$		81.019	36.233	-	441.74	-	-

irrigation) trailed in efficacy of seed weight head^{-1}. However, minimal seed weight head^{-1} was noted in N_1 = control (no nitrogen). As much as genotypes are concerned, the highest seed weight head^{-1} was observed in HO-1 whereas lowest seed weight head^{-1} was registered in Hysun-39. With regard to interactive effects, greatest seed weight head^{-1} was registered in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) with genotype HO-1 while least seed weight head^{-1} (g) was observed when N_1 = control (no nitrogen) was interacted with Hysun-39.

Biological yield (kg ha^{-1})

Nitrogen application through fertigation demonstrated considerable (P≤0.05) effects over the biological yield of sunflower (Table 3). Enhanced biological yield (kg ha^{-1}) was recorded under N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation), followed by N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation). Nonetheless, lowest biological yield (kg ha^{-1}) was noted under N_1 = control (no nitrogen). Genotype HO-1 surpassed Hysun-39 in biological yield (kg ha^{-1}). As regards interaction, greatest biological yield (kg ha^{-1}) was obtained in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) x HO-1 whereas minimum biological yield (kg ha^{-1}) noticed in N_1 = control (no nitrogen) x Hysun-39.

Seed yield (kg ha^{-1})

The statistical analysis envisaged that nitrogen application through fertigation demonstrated marked (P≤0.05) impact on the seeds yield (Table 4). Better seed yield (kg ha^{-1}) was documented in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation). N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing

Table 4: *Seed yield (kg ha^{-1}) and oil content (%) of sunflower as affected by nitrogen fertigation and genotypes.*

Fertigation method		Seed yield (kg ha^{-1})			Oil content (%)		
		Genotypes		Mean	Genotypes		Mean
		HO-1	Hysun-39		HO-1	Hysun-39	
N_1	Control (No nitrogen)	177.7	2128	2143 G	38.2	37.9	38.1
N_2	75 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	188.0	2270	2275 F	38.6	38.2	38.4
N_3	75 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd; both as fertigation)	193.0	2331	2333 EF	38.7	38.3	38.5
N_4	75 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	194.7	2376	2390 DE	38.9	38.5	38.7
N_5	100 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	199.7	2431	2434 D	39.0	38.8	38.9
N_6	100 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	204.0	2435	2450 CD	39.6	38.8	39.2
N_7	100 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	206.0	2482	2505 BC	39.8	38.8	39.3
N_8	125 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	220.3	2535	2587 B	40.5	39.2	39.9
N_9	125 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	228.3	2521	2527 B	40.5	38.9	39.7
N_{10}	125 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	231.7	2551	2603 A	40.6	39.3	40.0
Mean		2443	2415	--	39.4	38.7	--
Variable		Fert (F)	Geno (G)	F x G	Fert (F)	Geno (G)	F x G
CV		2.25			4.92		
SE		31.476	14.076	44.514	1.108	0.495	1.567
P value		0.000	0.167	0.999	0.715	0.128	0.999
$LSD_{0.05}$		63.720	-	-	-	-	-

time + ½ as fertigation at 2nd irrigation) ranked 2nd in performance. Least seed yield was observed in N_1 = control (o nitrogen). Among genotypes, more seed yield (kg ha^{-1}) was observed in HO-1 as compared to Hysun-39. The interaction of N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) with genotype HO-1 was found best and produced improved seed yield (kg ha^{-1}) in contrast to other interactions. Nonetheless, the interaction of N_1 = control (no nitrogen) with genotype Hysun-39 resulted in lowest seed yield (kg ha^{-1}).

Oil content (%)

Nitrogen application through fertigation caused significant (P>0.05) effect on oil content (%) of sunflower (Table 4). In case of nitrogen application methods numerically greater oil content was recorded in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation), followed by N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation). Nevertheless, least oil content (%) was observed in N_1 = control (no nitrogen). As regards genotypes, superior oil content (%) was observed in HO-1 over genotype Hysun-39. In case of interactive effects, numerically more oil content (%) was noticed in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) x HO-1 while minimal oil content was observed in the N_1 = control (no nitrogen) interacted with Hysun-39.

Chlorophyll content (µmol m^{-2} of leaf)

The effect of nitrogen application by fertigation methods was not substantial (P>0.05) on chlorophyll content (µmol m^{-2} of leaf) of sunflower (Table 5). As regards nitrogen application methods, numerically higher chlorophyll content (µmol m^{-2} of leaf) was noted under N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) whereas, N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation

Table 5: *Chlorophyll content (µmol m^{-2} of leaf) and crop growth rate (g m^{-2} day^{-1}) of sunflower as affected by nitrogen fertigation and genotypes.*

Fertigation method		Chlorophyll content (µmol m^{-2})			Crop growth rate (g m^{-2} day^{-1})		
		Genotypes		Mean	Genotypes		Mean
		HO-1	Hysun-39		HO-1	Hysun-39	
N_1	Control (No nitrogen)	177.7	43.2	43.2	1.5	1.4	1.4 C
N_2	75 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	188.0	43.5	44.1	1.9	1.4	1.4 BC
N_3	75 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd; both as fertigation)	193.0	44.2	44.5	2.2	1.8	2.0 BC
N_4	75 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	194.7	44.3	45.3	2.3	1.9	2.1 BC
N_5	100 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	199.7	44.4	46.2	2.5	2.0	2.2 BC
N_6	100 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	204.0	45.7	46.9	2.5	2.0	2.3 BC
N_7	100 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	206.0	47.0	48.9	2.6	2.5	2.5 B
N_8	125 kg N ha^{-1}: 2 splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation)	220.3	52.5	52.9	2.9	2.7	2.8 AB
N_9	125 kg N ha^{-1}: 2 splits (½ at 1st irrigation + ½ at 3rd irrigation; both as fertigation)	228.3	49.7	50.7	2.7	2.6	2.6 AB
N_{10}	125 kg N ha^{-1}: 3 splits (⅓ broadcasting at sowing time; + fertigation- ⅓ at 1st irrigation and ⅓ at 3rd irrigation)	231.7	53.0	53.2	3.4	2.8	3.1 A
Mean		48.3	46.9	--	2.6	2.1	--
Variable		Fert (F)	Geno (G)	F x G	Fert (F)	Geno (G)	F x G
CV		13.11			39.67		
SE		3.600	1.610	5.092	0.538	0.240	0.761
P value		0.061	0.370	1.000	0.018	0.098	0.972
$LSD_{0.05}$		-	-	-	1.089	-	-

at 2nd irrigation) ranked 2nd. However, minimum chlorophyll content (µmol m^{-2} of leaf) was noted under N_1 = control (no nitrogen). Genotype HO-1 gave greater chlorophyll content (µmol m^{-2} of leaf) over Hysun-39. The interaction of N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) with genotype HO-1 resulted in better chlorophyll content (µmol m^{-2} of leaf).

Crop growth rate (g m^{-2} day^{-1})

Nitrogen application through fertigation exhibited substantial ($P<0.05$) effects on crop growth rate (g m^{-2} day^{-1}) of sunflower (Table 5). As regards N application methods higher growth rate of crop was noticed in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation). N_8 = 125 kg N ha^{-1}: two splits (½ broadcasting at sowing time + ½ as fertigation at 2nd irrigation) proved 2nd in efficacy of giving crop growth rate (g m^{-2} day^{-1}). However, minimal growth rate of sunflower crop was noted in N_1 = control (no nitrogen). As much as genotypes are concerned, numerically higher growth rate was observed in HO-1 whereas lowest one was registered in Hysun-39. In case of interactive effects, numerically better growth rate (g m^{-2} day^{-1}) was documented in N_{10} = 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) with genotype HO-1.

Nitrogen is an essential plant nutrient to stimulate plant growth and development and ultimately yield and quality of the produce (Ullah *et al*., 2015). Nitrogen application at optimum rate improves the soil nitrogen status and subsequently causes increased crop yields (Kandil *et al*., 2017). Among the modern agro-management practices fertilizer application are imperative for boosting the growth and production of sunflower. The farmers in our country generally use the old method of fertilization application *i.e.* broadcasting. This method has so many disadvantages like uneven distributions of seeds, depth, and seed lying scattered being picked up by birds (Amin *et al*., 2006). Furthermore, nitrogen use efficiency is very low (30–40%) (Kumar *et al*., 2021). The findings of this study advocated that performance of sunflower almost in all growth and yield parameters was better when nitrogen was applied @ 125 kg N ha^{-1}: three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation). This superior performance may be attributed to most favorable dose and time of nitrogen application which rewarded the crop nutrient requirements at proper stage. Crops nutrient requirements vary at different growth stages. Nitrogen is the most important plant nutrient which is needed by plants in larger quantity and at different stages. When required nutrient is supplied to crop at proper time and in required quantity, the positive results could be achieved. The nutrients must be made available to the plants at the proper growth stage so as to avoid their excessive loss. Through fertigation fertilizers are applied in soluble form at critical growth stages with higher demand for nutrients. It ensures a regular and timely supply of nutrients without contaminating the environment through leaching (Asad *et al*., 2002). Fertigation is the technique of applying dissolved fertilizer to crops during their growth stages through an irrigation system (Nasim *et al*., 2012). Fertigation is the significant component of drip irrigation system and worldwide it has been proved beneficial method for crop fertilization, particularly under arid and semi-arid regions; and more particularly under water stress conditions (Wajid *et al*., 2017). Integration of fertigation with broadcasting @ 175 kg ha^{-1} provided required nitrogen to the crop that is why highest seed yield of sunflower was obtained at this combination of treatments. In the findings of research Rathod *et al*. (2017) reported that significant respective increase in seed yield of *Brassica juncea* (L.) was observed by 34.6, 53.1 and 72.1% under fertigation at 40, 80, and 120 kg N ha^{-1} over control. Moreover, lower seed yield of sunflower at control (no nitrogen) and other treatments might be due to deficit nitrogen availability to crop plants during the critical growth stages causing retardation of vegetative and reproductive growth and non-utilization of carbohydrates for end product synthesis. Genetic variability is very crucial item for selection of crop variety (Sujatha *et al*., 2002). Genetic similarities and differences existing in the genotypes are utilized efficiently as genetic resource in the breeding programs (Safavi, 2011). Hybrids of sunflower are more stable and highly self-fertile with a high yield performance and greater uniformity at maturity (Kaya and Atakisi, 2004). In our study genotype HO-1 surpassed Hysun-39 almost in all growth and yield traits, particularly seed yield (kg ha^{-1}). This superiority of HO-1 over Hysun-39 might be attributed to genetic potential and better adoptability of open pollinated variety (HO-1) under agro-ecological conditions of Tandojam. The early sunflower cultivars, having the highest yield can be recommended for the similar ecological conditions (Ozturk *et al*., 2017). Sunflower maturation under different environmental conditions would accumulate different concentration of oleic acid. Similarly, significant variations in linoleic acid content have also been observed among locations, planting dates and sunflower hybrids by Ahmad and Qureshi (2001). The variability in genetics of crop has much importance in breeding programs (Sujatha *et al*., 2002). In some cases, the hybrid genotypes have been found to be superior in terms of seed yield to their parental lines (Shahsavari *et al*., 2010). The highest 1000-seed weight and seed yield (kg ha^{-1}) were recorded from sunflower genotype Nsovak (Kandil *et al*., 2017).

Conclusions and Recommendations

The outcomes of present research showed that nitrogen application @ 125 kg ha^{-1} in three splits (⅓ broadcasting at sowing time + fertigation- ⅓ at 1st and ⅓ at 3rd irrigation) demonstrated substantial increase in seed yield (kg ha^{-1}) of sunflower over other treatments. Amongst the sunflower genotypes, more production potential was found in HO-1 which resulted in higher seed yield (kg ha^{-1}) in contrast to Hysun-39.

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Novelty Statement

Application of nitrogen to sunflower through fertigation in combination with broadcasting is a unique research under agro-climatic conditions of Tandojam, Sindh, Pakistan.

Authors' Contribution

Imran Ali Chandio: Conducted the trial, collected data and wrote article.
Muhammad Nawaz Kandhro: Supervised the scholar throughout the experiment and preparation of the article.
Qamaruddin Jogi: Gave his input in write-up of manuscript. G.M. Jamro supplied the research material.
Siraj Ahmed Channa: Contributed in statistical analysis of data.

Conflict of interest
The authors have declared no conflict of interest.

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